Design obstacle detection system for AUV Guanay II

C. Galarza, I. Masmitja, J. González, J.Prat, S. Gomariz, del Río. Joaquin

SARTI Research Group. Electronics Dept. Universitat Politècnica de Catalunya (UPC). Rambla Exposició 24, 08800, Vilanova i la Geltrú. Barcelona. Spain.+(34) 938 967 200, (cesar.mauricio.galarza@estudiant.upc.edu) (ivan.masmitja@upc.edu) (julian.gonzalez.agudelo@upc.edu) (jordi.prat@upc.edu) (spartacus.gomariz@upc.edu)(joaquin.del.rio@upc.edu)

Abstract: *The autonomous underwater vehicles (AUV) carry out inspection missions and intervention on known and unknown environments, where it is important to ensure their safety. The ability for obstacle detection and their avoidance during navigation is a requirement for safety. In this article is presented an obstacle detection system for the experimental vehicle Guanay II using mechanical scanning sonar, the Tritech Micron MK. Given that the Guanay II operates autonomously, a new software has been designed that allows adjustment, control, acquisition and processing of the sonar signals. Experimental tests done at sea have allowed us to verify the correct operation of the designed software, and to determine the optimal values of the fundamental parameters of sonar.*

Keywords: *AUV Guanay II, sonar MK3, obstacle detection, acquisition and signal processing, automatic operation.*

1. INTRODUCTION

The Guanay II [1] is an AUV developed by SARTI group from Universitat Politècnica de Catalunya, with the aim to provide a platform for measuring diverse oceanographic variables such as temperature and salinity of the water column, with high spatial and temporal resolution. This vehicle navigates on the sea surface to predetermined points, where it stops and makes vertical immersions to obtain a profile of a water column. The vehicle dimensions are 2300mm in length and 320mm in diameter. It has an empty weight of 90kg and may carry a payload of 4 kg.

The control system implemented in the Guanay II, allows the vehicle to track a default path for navigation. To ensure the safety of the vehicle, the vehicles has to implement a system for obstacle detecting and avoidances [2] [3] [4] [5]. In this paper, an obstacle detection system is proposed based on the mechanical scan sonar Tritech Micron MK3 [6].

Because this device has a closed control software "pro Seanet" [6], a new algorithm has been developed in LabVIEW programming environment from National Instruments, which is compatible with the vehicle control unit software and performs the adjustment, control, acquisition and processing of sonar signals.

Moreover, the paper presents all the experimental tests performed at sea, where the feasibility of this equipment for this application is verified. The tests have been carried out with different obstacles such as boats and walls. Finally, the results of the experimental tests are shown, and the obtained optimal values are given for the operating parameters of sonar, acquired based on theoretical results and the tests performed.

2. OBSTACLE DETECTION SYSTEM

The objective of this work is to develop a system able to detect obstacles in the trajectory navigation [3] [4] and which can be subsequently installed on the Guanay II AUV, becoming a subsystem of the overall control system of the vehicle.

This obstacle detection system is based on the mechanical scanning sonar Micron Tritech MK3 [6].

The MK3 sonar generates a beam with a vertical aperture of 35° (Figure.1.a) and a horizontal aperture of 3° (Figure.1.b). This beam rotates according to the value defined by the mechanical operating range, forming an effective detection volume for each beam position as shown in (Figure.2.b). In the vertical plane is formed an effective area of detection (Figure 2.a) that varies with respect to the distance "D" ($D < D_{max}$), the distance between a specific point and the sonar, see Figure 2.a and Figure 2.b. This configuration allows us to obtain, supposing the vehicle is immersed to a depth of 50m, a detection area of 7.3m wide by 98 m high at a distance of 70 m, and 0.1m wide by 1.4m high at a distance of 1 meter. This area is reduced proportionately, when the depth of operation of the vehicle is reduced, due to the cut suffered by the beam generated by the sonar as it hit the water surface (water-air), where it cannot continue to spread.

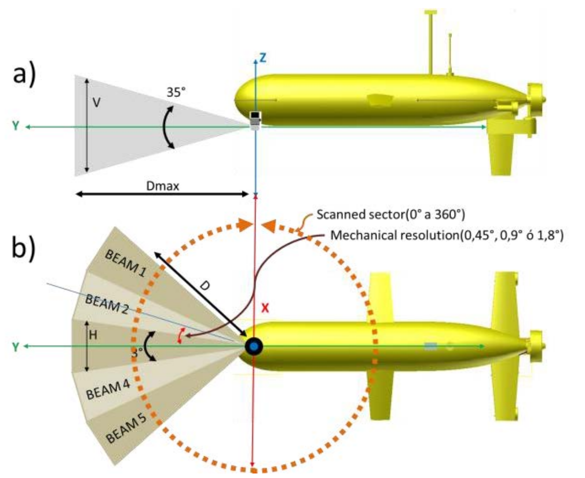

Figure 1 Guanay II, reference planes, a) vertical aperture 35 °, b) horizontal aperture sonar MK3 3°, distribution of multi point Beam.

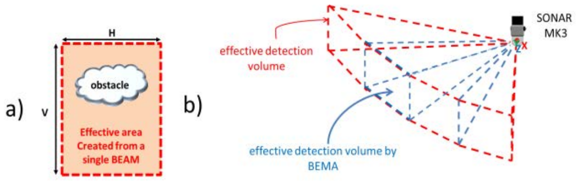

Figure 2 a) Effective area of detection b) effective volume by beam and total.

The MK3 sonar has a set of configuration parameters that have been properly adjusted to optimize their performance. The sonar configuration parameters are: mechanical operating range, turning mechanical resolution, number of points measured per beam, maximum operating distance of the sonar, input gain. A detailed description of each parameter is given bellow:

- The mechanical operating range ("RMOT" 0° to 360°). This parameter defines the start angle and the end angle sweep in degrees relative to the front of the sonar. Completing all the route marked by the mechanical operating range, the detection volume is generated (Figure 2.b).
- The mechanical resolution of rotation ("RMG"). This parameter limits the space in degrees between measurements (distance between the centers of the beams). It can be from 0.45°, 0.9° or 1.8°.
- The number of measurement points ("NPM"). Determines the number of samples which are measured from the received signal, with a maximum of 800 samples.
- The maximum operating distance of the sonar "D_{max}". It limits the range of the signal with a maximum of 75 meters.
- Input Gain (0-80dB). It is the gain factor by which the input data are multiplied.

The sonar can be configured through the RS232 or RS485 protocols. Tritech has its own software that lets you manage from a PC or laptop the configuration and signal acquisition. Given that the Guanay II operates autonomously a software has been designed that is compatible with the vehicle control unit for perform configuration, control, acquisition and processing of the sonar signals, as described in the following section.

3. ALGORITHM FOR THE OPERATION OF SONAR

The algorithm designed is divided into four functional blocks, as specified in Figure 3. Each of these blocks is explained in the following subsections.

A. Block 1: Communication and sonar settings

The sonar control commands and sonar operation through the RS-232 or RS485 port are given by the manufacturer in a series of technical notes [6]. .

The first step is to establish the communication between the platform and the device, the second step is to verify if the status of the device is correct: if it is connected and awaiting orders. In the third step the configuration status is verified. If the sonar is not configured, than the configuration is done, which sends the sonar parameters required for operation.

The previous configuration parameters are entered into the user interface. When the configuration is successful, the algorithms terminate and executes the data acquisition and display application illustrated in block 2.

B. Block 2: Acquisition and data visualization

After the setup sequence of the sonar operating parameters is terminated, the data acquisition algorithm is executed. In this part, the platform sends a request to the sonar data acquisition and receives the sonar responds with measurements, the internal mechanical rotation of the sonar is done automatically. Upon receiving this message, the algorithm organizes measurements information generating an image, and a copy of the message is saved in a file with the txt extension. This request and response algorithm runs in a loop indefinitely.

C. Block 3: Automatic processing for obstacle detection.

From the image generated in the block of data acquisition and display, an automatic identification of obstacles is performed. The identification is done based on the size, shape, location and hue of the object. As a result of this processing, an automatic graph is generated in which it shows each of the detected obstacles. Also it is created a data table with the coordinates of the location of these obstacles and their dimensions.

D. Block 4: GPS positioning

In parallel to the algorithms described above, is executed the algorithm for GPS positioning. For the tests presented in this papers it was used a Nokia LD-3W GPS (bluetooth); which will be replaced by the GPS installed in the Guanay II, when the system will finally beinstalled in the vehicle.

This algorithm initially establishes the communication with the Nokia GPS device, and captures the GPS position (latitude and longitude), which is used as reference for the measuring point. The latitude and longitude data acquired with the GPS are displayed in the main user interface and are stored in a file with txt extension.

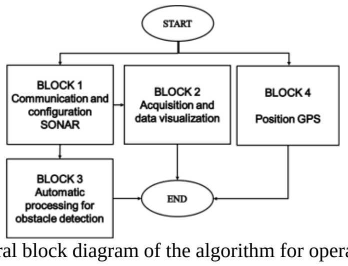

Figure 3 General block diagram of the algorithm for operate the sonar.

4. FIELD TESTS

All field tests were carried out in the port of Vilanova I la Geltru, Spain, with the main objective to evaluate and characterize the operation of the MK3 sonar to discriminate the walls that make up the piers and distinguish static boats of different sizes.

One of the points used for testing corresponds to the sports pier. This point was selected because of the short distance between the different obstacles (boats) and the physical structure of the place.
Configuration parameters are used:

Table I. Sonar settings

Settings	Value
Mechanical operating range	360°
Mechanical resolution of rotation	0.45°
Number of measurement points	396 P
Distance	30 m
Input gain	40dB
Depth	10 cm

In this scenario the walls of the pier is used as reference points in the analysis of results, therefore it was used a mechanical sweeping of 360°. The measuring maximum distance was adjusted to 30 m, with the purpose of obtaining data related to the sidewalls and boats anchored at the dock.

Figure 4(a) illustrates the data obtained during the test. These data have undergone a correction of brightness, contrast and color range, through a low-pass filter. The result is a reduction of uncertainty which allows us to obtain a clearer picture, as shown in Figure 4 (b).

When analyzing the filtered image obtained, resulting from the measurements, it can discriminate the location of empty spaces and the location of objects, but from this picture is not feasible to determine other characteristics related to shapes and sizes of these objects.

Although the purpose of this application is only to determine objects in the vehicle's path, it performed a comparison between satellite photo of the place, see Figure 5b, in which the tests were performed and the image obtained from the measurements (Figure 5a). With this comparison, it ratifies the discrimination of pier walls and other objects like boats present during the measurement.

Figure 6 shows the results obtained by applying automatic processing block for obstacle detection. With this algorithm you can locate each of the elements present in the test area and calculate their surface.

(a) (b)

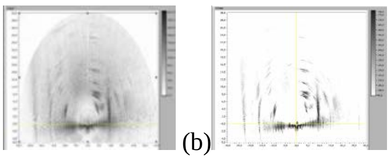

Figure 4 The signals acquired in tests performed at the port (a) original signal, (b) filtered signal

(a) (b)

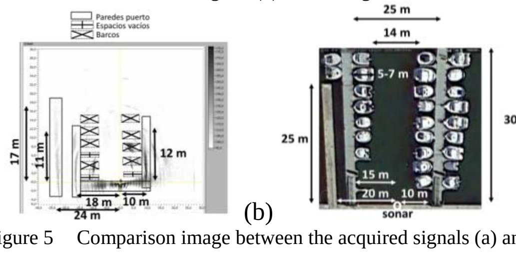

Figure 5 Comparison image between the acquired signals (a) and the map of the area taken from Google Earth (b) (latitude 41 ° 12'54 "length 1 43'53")

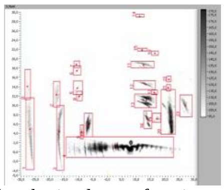

Figure 6 The results obtained at performing automatic processing for detecting obstacles

These tests, besides of verify that the developed system is able to discriminate the walls of jetties and boats, also allowed to:

a) Check the correct operation of the developed software
b) Calculate the time of operating, that is 23s or 92s, depending on the selected value of mechanical resolution of rotation (0.45 °, 0.9 ° or 1.8 °) for the next configuration parameters: RMOT = 360 °, NPM = 800 points, Dmax = 70 m.

5. DETERMINATION OF THE OPTIMAL VALUES OF PARAMETERS THE OBSTACLE DETECTION SYSTEM.

The optimal configuration of the operating parameters of the sonar for use in the Guanay II vehicle is established by combining the theoretical specifications, the results of field testing and the operations specifications of the vehicle.

From the specifications of vehicle operation parameters, the maximum speed of 1 m / s, maximum braking distance of 5 m, we estimated that the distance traveled by the vehicle during the time of execution of the algorithm lies between 23m and 96m.

With this information, and the theoretical specifications of sonar and the experimental tests, we set a series of multiple theoretical correlations between the parameters, the theoretical distance traveled, image resolution, mechanical operating range, number of points, maximum distance measurement, mechanical resolution of rotation and running time of the algorithm. For example, from the number of points (NPM), mechanical operating range (RMOT), rotational mechanical resolution (RMG) and the maximum operating distance (D_{max}), we can calculate the physical distance between points of measurement (D_{pp}), the image resolution (RI) and experimental tests run time of the algorithm is obtained (TEA). (See Table II),

Table II. Correlation between operating parameters with sonar RMOT=360º, RMG=0.9°, Dmax=70

NPM	Dpp[m]	RI [píxel]	TEA [s]
800	0.087	1600x1600	48
400	0.175	800x800	46
200	0.35	400x400	44

Another significant correlation is between the mechanical operating range (RMOT) and the operation speed of the vehicle (1m/s). This relationship determines the parameter TEA and from this the distance traveled during a run cycle. Assuming RMG=0.9°, NPM=800 and D_{max}=70m, the value of the parameters obtained for the runtime of the algorithm (TEA) and the distance traveled are shown in Table III.

Table III. Correlation between operating parameters with sonar RMG=0.9°, NPM=800, Dmax=70m

RMOT	TEA [s]	distance traveled
90°	12s	12m
120°	16s	16m
136°	18s	18m

The analysis of the above tables gives us the optimal operating parameters of sonar in the field in question. This configuration is given intable IV.

Table IV. Optimal parameters of sonar settings regarding the operating conditions of the vehicle.

Settings	Value
Mechanical operating range	90°
Mechanical resolution of rotation	0.9°
Number of measurement points	400 p
Distance	70 m
Input gain	40dB

The mechanical operating range of 90°, which according to Table III gives the lowest TEA, allows us to verify a window navigation of 1 m by 0.7m at a distance of 0.5m from the sonar, which is adjusts with the physical dimensions of the vehicle and allows us to determine a free space for the horizontal travel of the vehicle.

It is proposed to use a NPM of 400 points given that according to the table II, it provides a D_{pp} of 0.175m which is an intermediate value between the other values of NPM. With this configuration is obtained an image with a resolution of 800x800 pixels and an execution time of the algorithm of 12s. Therefore, if the vehicle navigates with maximum forward speed of 1 m/s, when the sonar finish a scan of 90°, the vehicle will advance 12 m.

The analyze, in a single sweep a distance of 70 m, allows us to evaluate the current situation and to take the necessary actions in advance, to prevent any collision.

With respect to the input gain parameter of the sonar, the manufacturer recommends the use of a a value between 40% and the 51%. In this case it´s assumes a value of 40 dB equivalent to 50% the maximum value (80dB). In the tests performed, with higher values the errors in the quantification of the signal result in false interpretations of data. Lower values do not have adequate sensitivity levels.

6. CONCLUSIONS

According to the studies carried out, as well as the results obtained in the present work, we conclude that the obstacle detection system developed for the Guanay II experimental vehicle using the Micron Tritech MK3 mechanical scanning sonar, it conforms to the physical characteristics and technical requirements of the vehicle.

The tests performed has allowed us to validate the designed software by which we achieved the configuration, control, acquisition and processing of signals from sonar.

The results are highly satisfactory, the developed software ensure the ability to detect and discriminate objects and structures in the vehicle's path. During the autonomous navigation mode, the sonar information obtained and conveniently processed will be useful either for surface navigation or underwater navigation.

We have determined the optimum configuration for the operating parameters of sonar based on theoretical specifications of the sonar, vehicle operating specifications and practical results obtained in field tests for a specific field. It will require further field tests in new areas of operation to corroborate and correct, if necessary, the proposed values, before installation in the vehicle, and subsequently the installation, There will be required navigation functional tests, that allow us to determine the real performance of the subsystem.

REFERENCES

[1] Gomariz S, Masmitjà I, González J, Masmitjà G, Prat J. "GUANAY II: an autonomous vehicle for vertical/horizontal sampling".Journal of marine science and technology, 2014.

[2] George C. Karras, Charalampos P. Bechlioulis, Hashim Kemal Abdella, Tom Larkworthy, Kostas Kyriako poulos and David Lane. A Robust Sonar Servo Control Scheme for Wall-Following using an Autonomous Underwater Vehicle, 2013 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), November 3-7, Tokyo, Japan, 2013.

[3] Ghatak A, D.K. Pratihar, C.S. Kumar. Online Measurement of Obstacles' Distances Using Forward Looking Sonar Sensor Mounted on an Experimental AUV, IEEE,2006.

[4] Ribas D, N. Palomeras, P. Ridao, M. Carreras and E. Hernandez. ICTINEU AUV Wins the First SAUC-E Competition, IEEE International Conference on Robotics and Automation Roma, Italy, 10-14 April, 2007.

[5] Philipp Woock, Christian Frey, Deep-Sea AUV Navigation Using Side-scan Sonar Images and SLAM, 978-1-4244-5222-4/10/IEEE, 2010.

[6] Tritech, Micron Sonar, Document, Product Manual, Document, software notes for controlling and operating RS 232 Sonar: 0650-SOM-00003, 0650-SOM-00004, Issue: 02.2013.